MAKING RELIABILITY A REALITY

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Introduction

There has been a significant push to strive for very high levels of weapon system reliability, sometimes referred to as "ultra reliability." Recent *Army AL&T* articles have stressed the importance of increasing reliability well beyond legacy values. Draft reliability requirements for the Future Combat Systems (FCS) are 4 to 12 times current values, and numerous organizations are suggesting that even higher levels are needed. These high levels of reliability will not be achieved with legacy reliability design practices. Recognizing that very high levels of reliability are required for our future systems, the Army must make major changes to legacy design practices to make higher reliability a reality. This article discusses some of the changes that must occur if we are to make ultra reliability more than just a slogan.

Reliability Predictions

The reliability portions of our contracts often take considerable space addressing reliability predictions. A reliability prediction may have little or nothing to do with the actual reliability of the product and can, in fact, result in poor design practices. For example, when 9 contractors came in with separate radio designs and predictions, subsequent testing showed that the reliability predictions ranged from 30 to 3,900 percent of the actual values. Contractors and subcontractors who frequently quote predictions may not understand the engineering and design considerations necessary to minimize risk and to produce a reliable design. In many cases, the person producing the prediction may not be a direct contributor to the design team. The historic focus on the accounting of predictions versus the engineering activities needed to eliminate failures during the design process has significantly limited our ability to produce highly reliable products. High reliability is not obtained through reliability predictions.

Real Reliability Models

When most people think of reliability models, they think of reliability block diagrams; failure modes, effects, and criticality analysis; fault trees; and reliability growth. When directly used to influence the design team, or when used by the Army to manage reliability progress, these tools can be extremely useful to focus engineering and testing efforts. However, the most important reliability tools are the structural, thermal, fatigue, failure mechanism, and vibration models the design team uses to ensure that they are manufacturing a product that will have a sufficiently large failure-free operating period. A good contractor routinely conducts thermal and vibration analyses to address potential failure mechanisms and failure sites (i.e., a physics-of-failure approach to reliable design). These analyses can include the use of fatigue analysis tools, finite element modeling, dynamic simulation, or heat-transfer analyses. Without such engineering analyses, the risk of failure is very high.

Reliability Is Affordable

When reliability is designed into systems early, many potential failure mechanisms and sources of failure can be eliminated with little cost. However, as time goes on, the cost to fix failures that were not addressed earlier in the design phase can become very significant. Early analysis of the engineering design, combined with early low-level testing and substantial integration testing, can greatly improve the reliability of the product before designs are locked in, and well before any formal testing program.

Many individuals still equate high reliability to gold plating (i.e, using more expensive materials or exotic designs). High reliability is the direct result of a strong engineering design effort combined with smart testing and management focus. As an example of how small investments can make a big difference, a reliability structural and thermal analysis for a circuit board can be completed for as little as $15,000 plus the cost of highly accelerated life testing (HALT) if confirmation is required. Based on just one of the projects the U.S. Army Materiel Systems Analysis Activity worked on, more than $27,000,000 was saved by identifying problems with a single circuit card.

By one estimate, operations and support (O&S) costs represent 60 percent of total life-cycle costs. Reliability improvements directly influence the majority of the O&S cost contributors. Throughout the life cycle of a major weapon system, moderate improvements in reliability can result in savings of hundreds of millions to billions of dollars.

Testing

Even with today's failure mechanism models and engineering tools, there is still a need for smart and focused testing. Lower-level testing (e.g., HALT) is critical for precipitating failures early and identifying weaknesses in the design. Integration testing is critical for identifying unforeseen interface issues. Some programs include these lower-level tests; however, many do not or the tests are performed on only a small subset of the components.

Developmental testing (DT) serves as one of the last opportunities to fix remaining problems and increase the probability of system success. Some programs undergo very limited or no formal DT. When a system meets the reliability requirement in DT, there is a 68 percent chance it will meet the operational testing (OT) reliability requirement. If the system fails in DT, there is only an 18 percent chance it will meet the OT reliability requirement. Significant program setbacks often happen when testing is reduced or eliminated to meet schedule or cost constraints. In some cases, the systems fail and have to repeat OT. In other cases, the price is paid in O&S costs for years to come. It is not uncommon for programs to have such short operational test durations that the contractor has to design to a reliability level several times higher than the requirement (almost ensuring failure) to demonstrate the reliability requirement.

Early low-level testing, along with focused higher-level testing, is key to producing products with high reliability. Without comprehensive lower-level testing on critical subassemblies, and without significant integration and developmental testing, there is little likelihood that high levels of reliability will be achieved.

COTS Equipment

Commercial off-the-shelf (COTS) equipment represents a great opportunity to improve reliability, reduce costs, and leverage the latest technologies. However, COTS does not imply that engineering analyses and early testing be abandoned. We frequently hear the expression, "that piece of equipment is COTS, so its reliability is what it is." Thermal, vibration, fatigue, and failure mechanism modeling, combined with early accelerated testing, can quantify and qualify the risk of COTS equipment failing in the military operating environment. We still have cases where a major COTS failure mode is discovered relatively late in the program.

Often COTS equipment data are proprietary; however, there are usually workarounds that can be used to develop data that can support sufficiently detailed engineering analyses. Relatively simple vibration and thermal analyses can detect potential "showstoppers." The showstoppers that have emerged because of inadequate early analysis have cost the Army millions of dollars and have significantly slowed the fielding of certain critical systems.

Incentives

For many procurements, the contractor does not have a strong incentive to make the product reliable. Even when reliability is mentioned in the Statement Of Work (SOW), the weight of reliability in the selection criteria is usually small. Contractors must bid low to be competitive, and when they have to trim their programs, reliability is often one of the first areas to go. To complicate things further, contractors typically make significant profit from follow-on replenishment spares. Unless the contractor sees value in directing and resourcing the design team to achieve high reliability, the Army will continue to field equipment with reliability values that fall far short of what commercial consumers typically experience.

Most contractors have the engineering staff and technical know-how to produce highly reliable systems. If the Army made reliability one of its high priorities in the SOW and specifications, and provided incentives, major Defense contractors would develop highly reliable systems. If this is not done, then reliability efforts will continue to consist of predictions and documents that do little to improve fielded systems.

Conclusion

There is little doubt that Army legacy reliability practices have produced low reliability values. Reliability efforts must be changed if the Army hopes to achieve the reliability requirements and footprint reductions envisioned for the FCS and other Army systems. For the most part, contractors have the capability to design equipment that achieves much higher levels of reliability than we see today—without huge increases in cost. However, today, they do not have the incentives to do so.

We must also become much more involved in the contractor's engineering efforts. This does not mean verifying that contractors have made reliability predictions that exceed the requirement. It means engaging contractors to see what their finite element, thermal, and vibration modeling is showing them; seeing that they understand what failure mechanisms are putting them most at risk; and examining their low-level testing programs. The Army needs to be a smart buyer.

To achieve ultra reliability, Army acquisition personnel and contractors must understand the difference between reliability predictions versus building reliability testing into the design phase of weapon systems. It is crucial that the Army specify that contractors perform lower level testing on critical subassemblies as well as integration and development testing. It is important, too, that the Army measure the risk of COTS equipment failing in the military operating environment. The cost of finding failures early is much less than paying inflated operating costs during the life cycle of a failure-prone weapon system. These changes in weapon systems design will ultimately lead to ultra reliable Future Combat Systems.

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